37. A method for image correction in a microscope comprising,

a) passing a laser beam through a beam splitter to form separate beams 1 & 2,

b) directing beam 1 through a first array of pinholes to illuminate an objective and define an object beam,

c) directing beam 2 through a second array of pinholes to a collimating lens to define a reference beam and then into interference with said object beam in a recording medium to define a hologram,

d) removing said first array of pinholes and replacing said pinhole array with an article to be viewed and

e) illuminating said article by a beam of the same wavelength as said laser beam so that light therefrom passes through or reflects off said objective and through an imagining lens to diffract through or off said hologram to reconstruct the original reference beam but with article information retained, to correct for defects in said objective and to provide an accurate image for viewing.

P4

REMARKS.

Claims 1 -- 8, 12 -- 26 & 29 -- 39 are in the present application. Six of the claims have been amended, as indicated above, for clarity and no matter has been added.

Figures 1 -- 16 are believed sufficient to meet the previous objections to them as to claims 1 2, 19 & 21, as raised in the Office Action dated 9 - 9 - 02. That is, these drawings are believed sufficiently detailed to those skilled in the art. Some of these drawings will be discussed further below.

The Office Action rejection of claim 36 as indefinite under 35 USC 112, first paragraph, as containing subject matter not sufficiently described in the specification so as to enable one skilled in the art to make or use such invention, is respectfully traversed. That is, doubt is expressed by the Office Action that the reconstructed or conjugated reference light will be able to interfere with the reference light beam itself, to create interference patterns.

As to enabling disclosure, the Examiner is referred to page 14 of the specification, attached hereto as Exhibit C, as it refers to Figure 15. As disclosed, original reference beam 137 is transmitted through the hologram 141 interfering with the reconstructed reference beam 149, producing fringes over the image as seen by the viewer, all as shown

in Figure 15 and described in the text on page 14. That is, as will be well understood by those skilled in the art, after the hologram 141, both beams 137 and 149 flow together through lenses 148 and 152 to the viewer, per Figure 15, and even though the two beams flow in the same direction, interference patterns are generated. This result is attested to in Applicant's 's Declaration under 37 CFR 1.132 (herein Rule 132) as signed by him on 6 December 2002 and mailed to the USPTO on that date. The above Office Action mentions receipt of such Declaration in paragraph 9 thereof.

In that Declaration, Dr. Andersen affirms the validity of the method shown in Figure 15 for making small height measurements at various points on an article as described in paragraph 5 and in paragraph 6, he notes the virtue of employing an array of pinholes, in the method of Figure 15, to obtain a contour map that cannot be realized by use of a single pinhole.

Further, Dr. Andersen states in paragraph 4 of the Declaration, that the essentials of holographically corrected microscopes are clearly shown in the drawings of this application in, e.g., in Figures 4, 6, 12 & 14, which are recognized as microscopes by those skilled in the art.

Accordingly, the disclosure of claims 36 is believe sufficiently enabling to those skilled in the art, to make or use the present invention as claimed.

The Office Action rejection of claims 1, 2 - 8, 12 - 14,19, 21 -- 26 & 29 - 31, as indefinite under 35 USC 112, as to whether applicant had, at the time of filing the present application, possession of the claimed invention, is respectfully traversed.

This rejection is not understood in view of the explanation provided in paragraph 4 of Dr. Andersen's above Rule 132 Declaration and his Paper attached thereto as Exhibit A. Further, such rejection seems to be contradicted by paragraph 9 of the present Office Action which states that the above Declaration is sufficient to overcome the previous rejection in an Office Action dated 9 - 9 - 02, concerning the operational principle of the invention. That is, it is believed that the above rejection no longer applies.

The Office Action rejection of claims 1, 2 - 8, 12 - 14, 19, 21 - 26 & 29 - 31, as indefinite under 35 USC 1 12th, first paragraph, as containing non-enabling subject matter, is respectively traversed. The gist of this paragraph 4 is that it is not seen how a holographic image corrector can comprise a microscope or how an objective optical

system can comprise a microscope but only supports that the latter system may be employed in a microscope. Further, the Office Action would have applicant distinguish between a holographic image corrector and an objective optical system. Here, the applicant agrees with the Examiner that the two systems are not the same. That this is so is indicated in Exhibit B hereof, where a summary of the invention is given on pp. 3 & 4 of the specification. Here we see that the image corrector of the invention includes paragraphs a), b), c) & d), while the optical system is described just in paragraph a) thereof. That is, the optical system is but a component of the image corrector of the invention.

Referring again to paragraph 4 of the Office Action, the Examiner states that it is clearly known to one skilled in the art that the essential elements of a microscope include a) an objective optical system and b) an eye piece optical system and concludes that an objective optical system is but a component of a microscope. Assuming the above statements to be true, if we turn to Figure 4 of the present disclosure, we see the above two optical systems in such Figure. That is, we see the objective optical system and the eye-piece optical system and thus we have the image corrector of the invention configured in a microscope as shown in such Figure and discussed in the specification on page 7, lines 10 to 28. Note in line 26, that it is stated that "This will mean that the device (of Figure 4) <u>operates like a conventional microscope</u>."

Also recall that in paragraph 4 of applicant's above Rule 132 Declaration, it is stated, under the sanctions of paragraph 7, that the essentials of holographically corrected microscopes , per the invention, are clearly shown in the original drawings of the above application, e.g., as Figures 4, 6, 12 & 14.

Thus it is requested that applicant's image corrector, per the above Summary of the invention on pp. 3 & 4 of Exhibit C, be recognized as it is clearly defined in such Summary, in paragraphs a), b), c.) & d). and not be limited to a mere hologram plate that appears in paragraph c) as but a component of the image corrector of the invention. Remember that it is the applicant who is the lexicographer in his application and can define an image corrector in his specification to include a microscope.

Referring now to claim 1, as amended, there is defined an image corrector, (which is similar to the above Summary), comprising a microscope which has (per the

Examiner's above 2 point criteria, in paragraph 4 of the Office Action) in claim paragraph a), an objective optical system and in paragraph f), a viewing optical system so as to recite the essential elements of a microscope.

Note where the above Office Action refers to an eye piece optical system, claim 1. f), as amended, refers to a "corrected image of said article for viewing" (e.g., per Figure 4) since the viewing can be done by eye or camera.

The above discussion as to the sufficiency of claim 1 is believed to apply to all of the claims of record, including the claims amended herein, which are 1, 2, 18, 21 & 37.

As to claims 18 and 37, where objection is made by the Office Action to the inclusion of the phrase "in a recording medium", such phrase has been deleted from claims 18 & 37, as indicated in Exhibit A hereof

The Office Action rejection of claims 1,2, 8, 12 -- 14, 15 -- 17, 18, 19, 20, 21 -- 26, 29 -- 31, 32 -- 36, 37 & 39, as obvious under 35 USC 103 a) over the patent to Leith (' 655), in view of patents issued to Reynolds et al ('100) and Fusek et al (' 481), is respectively traversed. Leith employs a hologram to correct for aberrated waves or for a lens or discloses producing an off-axis hologram (so as to produce a corrected image of an object in an off-axis position per his Figure 28), but doesn't suggest an application for his optical system, such as constructing a microscope of low-cost defective lenses.

The Office Action goes on to say the Leith patent may be applied to any optical system including applicant's holographic microscope though Leith makes no suggestion of applicant's claimed microscope structure nor does any reference yet cited. It is hardly believed that Leith's generalized off-axis holographic lens correction system can foreclose patents in future inventions in useful holographic applications, not suggested in the prior art.

Paragraph 6 of the Office Action, in the lower half of page 5, goes on to note that the manner in which a claimed apparatus is intended to be employed does not differentiate the claimed apparatus from a prior apparatus satisfying the claimed structural limitations. Here, two points come to mind. The first is that applicant's claimed microscope structure does not appear in the cited art. The second point is that while a different use does not add novelty to a known apparatus, the same is not true of method claims, for which recitation of new use it is highly suitable. Here method claims

such as 15, 19, 20, 32, 37 & 39 recite methods for image correction in a microscope to provide a corrected image of an article, which application of a hologram is not suggested by the cited art and novelty of such claims is indicated.

As for the Reynolds and Fusek patents, it is agreed that these references disclose the use of a pinhole in an optical circuit. However applicant does not claim to have invented the use of a single pinhole in an optical circuit or a method for producing an off-axis hologram. What applicant has invented, is a new and useful application, that of holographically corrected low-cost quality microscopes, which application is not suggested by the cited references.

As for applicant's claimed a array of pinholes, of claim 21 and later claims, the Office Action admits that no reference has been found that teaches such array and falls back on "an obvious matter of design choice", since a single pinhole is known. However, no reference mentions such a choice. This suggests that applicant's claimed array of pinholes, in an optical circuit, is novel and should be so recognized. That is, such array of pinhole's has not been seen in the prior art lens correction and certainly not in a microscope, which should highlight the novelty of applicant's claims.

As to claim 36, as discussed above, it is believed that such claim is highly enabled to those skilled in the art, as discussed above. Further as shown in applicant's above Rule 132 Declaration, applicants corrected microscope, per claim 36, is capable of the unheard-of advantage of making small height measurements on various points of an article, as described on page 14 of the specification, in light of Figure 15 herein. The novel process includes employing interfering laser beams and a hologram to produce fringes over the image, as seen by the eye at lens 152 of Figure 15, which fringes translate into a contour map of elevations of points on the surface of the article. And no art has been cited that remotely suggests the novelty of this claim.

A further novelty of claim 36 is that such method employs an array of pinholes. That is, per such claim, a reference beam is added to the reconstruction of a hologram (e.g., per Figure 15) that interferes with the hologram image so as to produce a fringe pattern thereon, to permit extracting height information for a contour map of the article viewed. It happens that this contour map is only possible using an array of pinholes, which is believed to highlight the novelty of such array as well as the novelty of the

contour map method of claim 36. That is, claim 36 is believed twice novel.

Also in related claims herein such as claim 21, the use of an array of pinholes to correct an objective in a microscope is a structural feature not found the prior art and is believed to have considerable novelty.

In view of the foregoing, the claims of record, as amended, are believed distinguished over the applied art and in condition for allowance.

In accordance with Section 714.01 of the M.P.E.P., the following information is presented in the event that a call may be deemed desirable by the Examiner: Thomas C. Stover, (781) 377-3779.

Respectfully submitted,

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<u>Marked-up version of claims to show changes made to above clean version.</u>

Amend the following claims.

1. (six times amended) A holographic image corrector comprising, a microscope which has,

a) an optical system having an objective,

b) at least one pinhole mounted before said objective,

c) means for recording the characteristics of said objective by sending a first laser beam through said pinhole and through said objective or reflecting said beam therefrom to form an object beam,

d) means for intersecting said object beam with a reference laser beam in a recording medium to form a hologram of said objective, said laser beams being coherent,

e) means to replace said pinhole with an article and

f) means to illuminate said article with a beam of the same wavelength as said laser beams so that light therefrom passes through or reflects off said objective and diffracts through or off said hologram and provides a corrected image of said article <u>for viewing</u>.

2. (four times amended) A holographic image corrector comprising, a microscope which has,

a) an optical system having an objective,

b) a pinhole mounted before said objective,

d) means for recording the characteristics of said objective by sending a first laser beam through said pinhole and through said objective or reflecting said beam therefrom to form an object beam

d) means for intersecting said object beam with a reference coherent laser beam in a recording medium to form a hologram of said objective,

e) means to replace said pinhole with an article and

f) means to illuminate said article with a beam of the same wavelength as said laser beams so that light therefrom passes through or reflects off said objective and diffracts through or off said hologram and provides a corrected image of said article <u>for viewing</u>.

18. (five times amended) A method for image correction in a microscope comprising,

a) passing a laser beam through a beam splitter to form separate coherent beams 1 & 2,

b) directing beam 1 through a first pinhole to illuminate an objective and define an object beam,

c) directing beam 2 through a second pinhole to a collimating lens to define a reference beam and then into interference with said object beam in a recording medium to define a hologram,

d) removing said first pinhole before said objective and replacing said pinhole with an article to be viewed and

b) illuminating said article by a beam of the same wavelength as said coherent beams so that light therefrom passes through or reflects off said objective and through an imaging lens to diffract through or off said hologram to reconstruct the original reference beam but with article information retained, to correct for defects in said objective and to provide an accurate image [in a recording medium or] for viewing.

21. (four times amended) A holographic image corrector comprising,
a microscope which has

a) an optical system having an objective

b) an array of pinholes mounted before said objective,

c) means for recording the characteristics of said objective by sending a first laser beam through said array and through said objective or reflecting said beam therefrom to form an object beam and

d) means for intersecting said object beam with a reference coherent laser beam in a recording medium to form a hologram of said objective,

e) means to replace said array with an article and

f) means to illuminate said article with a beam of the same wavelength as said laser beams so that light therefrom passes through or reflects off said objective and diffracts through or off said hologram and provides a corrected image of said article <u>for viewing</u>.

37. (five times amended) A method for image correction in a microscope comprising,

a) passing a laser beam through a beam splitter to form separate [coherent] beams 1 & 2,

b) directing beam 1 through a first array of pinholes to illuminate an objective and define an object beam,

c) directing beam 2 through a second array of pinholes to a collimating lens to define a reference beam and then into interference with said object beam in a recording medium to define a hologram,

d) removing said first array of pinholes and replacing said pinhole array with an article to be viewed and

e) illuminating said article by a beam of the same wavelength as said laser beam so that light therefrom passes through or reflects off said objective and through an imagining lens to diffract through or off said hologram to reconstruct the original reference beam but with article information retained, to correct for defects in said objective and to provide an accurate image [in a recording medium or] for viewing.

Exhibit A

Also, many schemes using holography for obtaining better microscopic images have been suggested. These include taking holograms of the object through a conventional microscope and then using the information contained in the hologram to produce large scale, aberration-free images of the object. This method relies on the use of a high quality microscope to begin with and, as such, has the usual problems associated with such methods including small working distance and expensive optical components. Other methods have corrected for the optics in a poor-quality microscope by holographic correction of the microscope optics, but these still require a second, high quality microscope for final viewing of the images. Both of these methods also suffer from the fact that the hologram is uniquely recorded for every sample, which is a problem when it comes to observing objects in real-time.

In the prior art is USP 5,426,521 to Chen et al (1995) which discloses correction of aberrations (which have to be first calculated) in an optical system by employing a liquid crystal panel which simulates a hologram from the calculations Also USP 5, 657,168 to Maruyama et al (1997) discloses correcting aberration of an objective lens with an element having almost no power. However neither of these references discloses correcting aberrations in an optical system by use of a true hologram. And there is need and market for such aberration correction which permits relatively clear images to be obtained from flawed and thus low cost objectives.

There has now been discovered method and apparatus for correcting aberrations in an objective optical system that permits the use of relatively large and/or low cost objectives such as a lens or mirror, in which the imperfections thereof can be reduced or nullified to obtain an improved image of the object so viewed.

SUMMARY OF THE INVENTION

Broadly the invention provides an image corrector which includes,

a) an optical system having an objective,

b) means for recording the characteristics of the objective by sending a first coherent beam therethrough or reflecting the beam therefrom to form an objective beam,

c) means for intersecting the objective beam with a coherent reference beam in a recording medium to form a hologram thereof and

d) means to illuminate an object with a coherent beam so that light therefrom passes through or reflects off of the objective and defracts through or off the hologram, to reduce or correct aberrations in the objective and provide a relatively clear image of the object.

The image corrector of the invention also provides for an aberration correction of an optical system, eg. a microscope, including where such system is of relatively large working distance from the object being viewed.

Definitions:

By "objective", as used herein, is meant a lens or concave mirror.

By "working distance", as used herein, is meant the distance between the objective and the object being viewed.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be come more apparent from the following detailed specification and drawings in which:

Figures 1 and 2 are schematic elevation views of hologram formation and use per the prior art;

Figure 3 is a schematic elevation view of recording of a hologram per the present invention;

Figure 4 is a schematic elevation view of a reconstruction of the hologram of Figure 3;

Figure 5 is a schematic elevation view of the recording of a hologram of a reflecting objective per the present invention;

Figure 6 is a schematic elevation view of a reconstruction of the hologram of Figure 5 and

Figures 7-10 are side and front elevation views of two elements employed in the objective optical system embodying the present invention.

Figure 11 is a schematic elevation view of recording of a hologram per the present invention;

such an objective element is believed able to use the extremely small wavelengths of X-rays to extend the microscope to very high resolution per the invention.

A further feature of this microscope is the possibility of making small measurements of the height of any points on the object. For this mode of operation, the recording is the same as before per Figure 11 but the reconstruction is modified as shown in Figure 15. The original reference beam 137 remains, on reconstruction, and a small portion of this beam will be transmitted through the hologram 141, interfering with the reconstructed reference beam (with the object information imprinted on it) 149, producing fringes over the image. If the original pinhole array was a flat substrate, these fringes represent a contour map of the height of points over the object. Using phase shifting interferometry techniques, the height of various features on the object can be calculated to a fraction of a wavelength of light. Once again, this figure (Figure 15) shows the set-up for a refracting objective, but this concept applies to the other types of objectives mentioned above. Also an example of the fringed image 90 of the invention, shown in Figure 16, appears in the image plane 150 of Figure 15.

This microscope can have a large working distance, and as such, the diameter of the objective can be large so that the numerical aperture is large. Where the numerical aperture is large, very small details can be resolved. A large working distance means that this microscope can have applications in fields where a high magnification is desired, but close proximity to the sample is impossible. For example objects can be viewed inside vacuum systems (from the outside) in situations which could cause damage to the microscope such as explosive, corrosive, radioactive or other physically violent phenomena, or in various other applications (including gas-filled systems of, eg. argon) where it is desirable to have the microscope located some distance away, so that real-time operations can be carried out directly on the sample.

If the recording process takes place with a vacuum window between the pinhole array and the objective, such an arrangement can allow the hologram to correct for aberrations present in the window as well as in the objective. This makes it possible to have the microscope on the outside of a vacuum (or other) chamber, viewing accurate images.